Effect of Flyash on the Properties of Concrete and Construction Materials

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Abstract: **-Fly ash, a waste generated by thermal power plants is as such a big environmental concern. The investigation reported in this paper is carried out to study the utilization of fly ash in cement concrete as a partial replacement of cement as well as an additive so as to provide an environmentally consistent way of its disposal and reuse. This work is a case study on fly Ash collected from CTPS Bokaro .This research was experimentally carried out to investigate the effects of introducing Fly Ash(FA) as a Partial Replacement of Portland Slag Cement (PSC) on the physical and structural properties of Concrete.Consistency, Compressive Strength, Split Tensile Strength and Flexural Strength of concrete with 0% ,5% ,10% ,15% and 20% partial replacement of PSC with FA has been conducted and result is calculated at 7 and 28 days.**

Key words- **Waste, Thermal, Compaction factor, Split , Slump.**

I. INTRODUCTION

Concrete is the most widely used construction material for various types of structures due to its structural stability and strength. All the materials required for producing such huge quantities of concrete comes from the earth's crust. Thus, it depletes its resources every year creating ecological strains. On the other hand, human activities on earth produce solid waste in considerable quantities of over 2500 MT per year including industrial waste, agricultural waste and waste from rural and urban societies. Recent technological development has shown that these materials are valuable as organic and inorganic resources and can produce various useful products. Amongst the solid wastes, the most prominent ones are fly ash, blast furnace slag, rice husk ash, silica fume and demolished construction materials.

Fly Ash is a by-product of the combustion of pulverized coal in electric power generation plants. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. However, some of the mineral impurities of clay, shale, feldspars, etc., are fused in suspension and carried out of the combustion chamber in the exhaust gases. As the exhaust gases cool, the fused materials solidify into spherical glassy particles called Fly Ash. Due to the fusion-in-suspension these Fly Ash particles are mostly minute solid spheres and hollow ecospheres with some particles, which are spheres containing smaller spheres. The size of the Fly Ash particles varies but tends to be similar to slightly larger than Type I Portland cement. The Fly Ash is collected from the exhaust gases by electrostatic precipitators or bag filters.

Fly ash is used widely as a construction material, this waste material used as landfill or for soil stabilization. It is the non-combustion mineral portion of coal, generated in a coal combustion power plant. Since the 1950s, fly ash was slowly introduced to civil engineers as a valuable ingredient that can be used in concrete .It can improve many desirable properties of concrete in the fresh and hardened stages. Today It is used in concrete for several reasons such as improving the workability of fresh concrete, reducing of initial hydration temperature, sulphate resistance, improving the duration, and strength of hardened concrete.

Fly ash reacts with lime, the byproduct of the cement hydration, and creates additional Calcium Silicate-hydrate crystals, the component that provides strength in concrete. The proper replacement of cement with fly ash improves workability and performance of fresh and hardened concrete, as well as increase the final strength. Concrete with fly ash has a lower strength at an early age than Portland cement concrete. The slow hydration reaction rate and lower strength of fly ash concrete at an early age are the main reasons that civil engineers did not use fly ash in concrete for decades, especially in time dependant projects.

Fly ash particles are extremely hot when they are collected. While fly ash is cooling down, the small particles tend to adhere to the surface of bigger particles. The rough fly ash particles have lower reaction surface areas that reduce the hydration reaction rate of fly ash in concrete. Grinding is one of the methods that has been suggested to increase the reaction surface area of fly ash. Comparing the macroscopic pictures of ungrounded and ground fly ash shows that grinding the fly ash can remove the small particles from the surface and clean the topography of the fly ash particles.

II. MATERIAL AND METHODS

In this present work, a comprehensive experimental schedule is being formulated to achieve the objectives and scope of the present investigation. The whole experimental work is classified into Fly ash properties, Test of materials, Selection of mix design, Test of concrete, Test of Partially replaced PSC with FA, Composition of (Cement+FA) concrete.

The Fly ash samples from Chandrapura Thermal Power Station were collected directly from the same hoppers of electro static precipitators (ESP) in plastic. FA samples was air dried and pass through a 2mm sieve. The samples is analysed for bulk density, moisture content, specific gravity, water holding capacity, liquid limit, plastic limit, grain size distribution, and permeability. The test conducted on FA for the present research work are fineness test , bulk density , specific gravity and moisture content . The test results are given below in Table 1

Further the fineness test, Consistency test, Initial and final setting time, Soundness test and specific gravity for Portland cement was carried out. The fineness test was conducted by using 90 micron sieve as per IS 4301(part1).The consistency test, initial and final setting time test was conducted by Vicat apparatus as perIS 4301(part 4 & Part 5).The Soundness test was conducted by Le-Chatelliers apparatus as per IS 4301(part3) and Specific gravity of cement is obtained by using Pycnometer and Kerosene oil. The Test properties performed on cement are given below in table **2**. For all the experiment portable water was used. Further particle size distribution and fineness modulas test is mainly useful for finding and grading of both fine aggregate and coarse aggregate and determine the suitability of aggregate for production of concrete. The result of particle size distribution and the properties of fine aggregate is shown in table **3** and table **4**. Similarly For Coarse aggregate, Aggregate of size 20mm and 12.5 mm of specific gravity 2.79 and fineness modulas 6.687 were used. The physical properties of fine and coarse aggregate were given in table **5**. The specific gravity test is carried out on both fine and coarse aggregate as per procedure given in BIS(IS:2386 Part 3rd-1963).Water absorbtion over a period of 24 hour is calculated from the test data. The bulk density or unit weight of an arrangement gives valuable information regarding the shape and grading of aggregate the bulk density is nothing but the mass of aggregate in a given volume .This test is performed in accordance with BIS (IS:2386 Part 3rd-1963) on both fine and coarse aggregate. The Flakiness and Elongation Index tests are performed on coarse aggregates according to the procedure outlined in (BIS:2386 Part 1st-1963). These tests are useful for general assessment of aggregate .The standard limits for flakiness index is 25% and for elongation index is 30% as per IS :383:1970 . These tests are not suitable for aggregate size less than 6.3 mm.

For mechanical properties namely crushing value, impact strength, aggregate abrasion value of coarse aggregate are relevant to those specified in BIS (IS:2386 Part 4th-1963). The agreegate crushing value test gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. This test is conducted in accordance with BIS(IS:2386 Part 4th-1963) on coarse aggregate .The test specimen of aggregate size fraction 12.5-10mm was prepared using standard sieves and placed and then compacted with a tamping rod in a standard cylinder and levelled carefully. The plunger is placed on the top of the sample and a load is applied at a uniform rate for 10 minutes to reach a maximum value of 400 KN. The Sample is then removed and sieved through a 2.36 mm IS Sieve. The crushing value is nothing but the percentage of material passing through this sieve. According to BIS (IS:383-1970) the crushing value limited to 45% for aggregate used in concrete other than wearing surface and 30% for aggregate used in wearing surface such as runway , road and pavements. This aggregate impact value test gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregate differs from its resistance to a slow compressive load. This test is conducted on coarse aggregate as per the procedure given in BIS(IS:2368 Part 4th-1963). The sample is prepared in a similar procedure as in crushing value test. According to BIS (IS:383-1970) the aggregate is suitable for concrete other than wearing course if impact value is below 45% and is wearing surface such as runways, roads and pavements if impact load is below 30%.Similarly The aggregate abrasion value test is useful to measure the hardness or resistance to wear of aggregate by abrasion. The Los angles test is one of the methods available for measuring this abrasion value of coarse aggregate. This test is one of the methods available for measuring the abrasion value of coarse aggregate. This test is performed on coarse aggregate in accordance with BIS (IS: 2386 Part 4th-1963). The test sample selected is of two sizes 20-12.5 mm and 12.5-10 mm and each weight 2.5 kg. The sample is then placed in Los angles test machine along with the corresponding abrasive charges and the machine is rotated for about 500 revolutions at 30 revolutions per minute. The sample is then sieved through the 1.70 mm IS sieve and the retained sample is washed and dried. The difference in weight between original sample and retained sample expressed as percentage by original weight is the Los Angeles abrasion value. According to BIS (IS: 383-1970) the maximum value of abrasion is limited to 50% for concretes other than wearing surfaces and 30% for wearing surfaces.

When all the above process is completed then selection of mix design is done. Three different mix designs M_1, M_2 and M_3 were prepared for three different water-cement ratio to get M20. The most appropriate mix design was selected on the basis of slump value and compressive strength as shown in table **6**.

The target strength for M20 is given by

$$\vec{f}ck = f_{ck} + 1.65 \times S$$

$$= 20 + 1.65 \times 4$$

= 26.6 N/mm^2 ,selecting S = 4

M_3 is rejected as this mix design does not achieve the target strength after 28 days.

We observe very low degree of workability as per IS 456 in M_1, so we reject this mix design also. M_2 achieves the target strength of M20 and its slump comes in the range of low degree of workability as per IS 456. As per IS 456 in this range of workability, we can use this concrete in conditions of mass concreting; lightly reinforced sections in slab, beams, walls, columns; floors; hand placed pavements; canal lining; strip footing, etc.

So, we select the mix design M_2 for this project work and done all the relevant test for concrete.

Test of Concrete

General

In the present research work the test on concrete was performed on fresh as well as on hardened stage. Non destructive test on hardened concrete was also performed in this project work. Here we discuss tests on each stage separately.

Test on Fresh Concrete

Workability (Slump)

The properties of fresh concrete are assessed by workability in terms of slump value. To check the slump value of fresh concrete in the range of 25-50 mm, the slump cone test is conducted on all concrete mixes. The slump cone specified by BIS (IS: 7320-1974) is used to measure the slump of fresh concrete. The slump cone is placed on a smooth surface (metal base plate) and filled with concrete in three layers, each layer is compacted uniformly by 25 blows with a standard 16 mm diameter tamping rod, and the top surface is struck off by means of sawing and rolling motion of the tamping rod. The mould is lifted slowly without shaking and the unsupported concrete is the slump. Height of slump is measured.

Tests of hardened concrete

Compressive Strength Test of Hardened Concrete

The compressive strength is determined using 2000 kN compression testing machine in accordance with BIS (IS: 516-1959). A typical arrangement for compression testing of cubes is done.The compressive strength test is conducted on 150 mm size of cube at 7 and 28 days adopting wet curing process. Three cube specimens were tested after each curing period of 7 and 28 days. A total of 6 cube specimens were tested for compressive strength for each mix. The test result is presented and discussed below. The compressive strength is computed from following formula.

$$\text{Compressive strength} = \frac{P}{A}$$

Where; P: Ultimate compressive load on concrete (N)

A: Surface area in contact (mm^2)

Split tensile strength

The split tensile strength of concrete was determined after 7days and 28 days of curing on cylindrical specimens of 150 mm x 300 mm using 1000 kN compression testing machine as per the procedure given in BIS (IS: 5816-1999).

A bar of square cross section of size 10 mm was placed along the center of the base platen. The specimen is then placed in horizontal direction on this strip. Another strip of similar shape and size was placed on the cylinder exactly above and parallel to the lower strip. The machine was operated such that the upper platen just touches the top strip and then the load was applied at a rates of 1.2 to 2.4 N/mm^2/min throughout the test. The split tension stress is computed from the following formula.

$$T = \frac{2P}{\pi ld}$$

Where; T: Tensile Strength

P: Failure load

L: Length of cylinder

D: Diameter of cylinder

Flexural strength

This test was performed in accordance with BIS (IS: 516-1959) on prisms of size 100 x 100 x 500 mm after 28 days of water curing using 200 kN universal testing machine. The specimen was supported on two roller support spaced at 400 mm center to center. The load was then applied at a rate of 0.7 N/mm^2/min through two similar rollers mounted at third point of the span (133.3 mm center to center) till the failure occurred. The flexural strength is expressed as modulus of rupture and it is calculated based on the appropriate expression in code. Three samples are used for each mix of concrete and the average result is reported.

III. RESULTS AND DISCUSSION

The results of the PSC with FA, fresh concrete (Cement+FA), hardened concrete (Cement+FA) are discussed.

Study of Partially Replaced PSC with FA

Here, the different tests were conducted by replacing 0% , 5% , 10% , 15% and 20% PSC cement with FA. The results of different tests conducted on partially replaced PSC with FA are discussed below.

Consistency test

The value of consistency obtained for different percentage replacement is shown in table **7** and its variation is shown in fig 1. The properties of fresh concrete can be evaluated by slump cone test with W/C ratio 0.45. From Table **7** and Fig **1** we may conclude that the workability increases as the % replacement of PSC with FA increases.

Compressive strength

The value of compressive strength found for different percentage of replacement of PSC with RHA is present in table **8 and table 9** and its variation is shown in fig **2**.and fig 3.

Split Tensile Strength

The results of Split Tensile strength were presented in Table 10 and table11 and its variation is shown in fig4 and fig5. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000KN. The maximum increase in split tensile strength is observed at 15% replacement of fly ash. The optimum fly ash replacement percentages for tensile strengths have been found to be a function of w/c ratio of the mix. The optimum 28-day split tensile strength has been obtained in the range of 20%.

Flexural Strength Test

The experimental setup and method for calculating the value of flexural strength is already discussed previously. The values of flexural strength of M_0, M_5, M_{10}, M_{15} and M_{20} for 7 and 28 days are given in table 12and 13 respectively. The variations of flexural strength of the above mix are shown in graphs for 7 and 28 days in fig 6 and fig 7 respectively.

From table 10 and fig.3 , it is noted that the flexural strength increases gradually as the percentage replacement of PSC with FA increases after 7 days in the concrete mix.

For 10% partial replacement, flexural strength increases by 5.00% and for 15%, it increases by 15.0% w.r.t. flexural strength of normal concrete after 7 days.

However, there is very small increases in flexural strength up on 20% partial replacement of PSC with FA. So it may be concluded that 15% replacement may be allowed for the case of flexure strength.

It is observed from table 11 and fig 4 that the flexural strength increases gradually as the partial replacement of PSC with FA increases in the concrete mix after 28 days. For 10% partial replacement, flexural strength increases by 3.33% and for 20% replacement, it increases by 2.23% w.r.t. flexural strength of normal concrete after 28 days.

However, there is very small increases in flexural strength up on 20% partial replacement of PSC with FA. So it may be concluded that 15% replacement may be allowed for the case of flexure strength.

IV. CONCLUSION

This work relates the use of Fly Ash, a waste materials from the Industries which is used in M20 grade of concrete and recommends the approval of the material for use in concrete as a replacement material. The partial substitution of FA enables a gain of compressive, tensile and flexural strength of concrete up to an optimum value of replacement and also the wide use of FA is increasing in the construction industry which is discussed in the work which is a good sign in the way of our eco friendly environment as it is the largest waste mass which is generated from the industry.

The workability of fresh concrete is measured by slump cone test and it is formed that the workability of concrete increase as the partial replacement of PSC with FA increases .For 20% partial replacement of PSC with FA , Slump value increases by 38.10%.

The compressive strength of concrete increases upto 15% partial replacement of PSC with FA and afterwards decreases .For 15% partial replacement of PSC with FA , compressive strength increases by 11.99% and for 20% partial replacement it is 1.62%. After 28 days result thus it may be concluded that the optimum percentage replacement of PSC with FA may be 15% and total percentage replacement may be 20% from compressive strength point of view.

The split tensile strength of concrete increases upto 15% partial replacement of PSC with FA and afterwards decreases .For 15% partial replacement of PSC with FA, split tensile strength increases by 14.12 % and for 20% partial replacement it is 5.2%. After 28 days result thus it may be concluded that the optimum percentage replacement of PSC with FA may be 15% and total percentage replacement may be 20% from split tensile strength point of view.

The flexural strength of concrete increases upto 15% partial replacement of PSC with FA and afterwards decreases .For 15% partial replacement of PSC with FA, flexural strength increases by 11.11 % and for 20% partial replacement it is 2.23 %. After 28 days result thus it may be concluded that the optimum percentage replacement of PSC with FA may be 15% and total percentage replacement may be 20% from flexural strength point of view.

FA has advantage in manufacture of FA bricks, making of Stabilised base course, structural fills, embankment and asphalt pavements as due to abundance of the FA produced from the NTPC and other industries and also the properties of FA makes it a substitute for soil and other materials to some extent as the construction materials.

We may conclude from this work that the addition of FA as a partial replacement of PSC in concrete improves the strength property of concrete .From results observed , we may say that the optimum percentage replacement of PSC with FA may be 15% and total percentage replacement may be 20%.

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IS Codes

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[4]. IS: 12269-1987 - 53 Grade Ordinary Portland Cement (Reaffirmed 2004)

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TABLE NO. 1 - PHYSICAL PROPERTIES OF FLY ASH, CTPS, BOKARO

Sl.no.	Test	Result
1.	Fineness	2%
2.	Bulk density	920 kg/m3
3.	Specific gravity	2.12
4.	Moisture content (%)	1.06

TABLE 2 PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT.

PROPERTIES	RESULTS	STANDARD LIMITS
Consistency	32%	-
Soundness	Expansion 3.0 mm	<10 mm
Initial setting time	75 minutes	>30 minutes
Final setting time	255 minutes	<600 minutes
Specific gravity	3.14	-
Fineness	2.83% retain on 90 micron sieve	<10 mm
Compressive strength 3days 7 days 28 days	N/mm2 19.85 23.45 35.98	N/mm2 >16 >22 >33

TABLE 3 SIEVE ANALYSIS OF FINE AGGREGATE

Weight of sample=1000 gms

IS SIEVE (MM)	Wt. retained (gms)	% retained	% Cum wt. RETAINED (gms)	CUMULATIVE % OF passing	REMARKS (REQUIRED AS PER IS)
4.75 MM	5	1.50	1.50	98.50	90-100
2.36 MM	23	2.30	3.80	96.20	75-100
1.18 MM	141	14.40	17.90	82.10	55-90
600 micron	245	24.50	42.40	57.60	36-59
300 micron	380	38.00	80.40	19.60	8-30
150 micron	185	18.50	98.90	1.10	0-10
TOTAL			244.90		

FINENESS MODULUS :- 244.90/ 100 = 2.45

TABLE 4: PROPERTIES OF FINE AGGREGATE

S. No	Property	Result
1	Specific gravity	2.69
2	Fineness modulus	2.45
3	Grading zone	II

TABLE 5 PHYSICAL PROPERTIES OF FINE AND COARSE AGGREGATE

S.No.	PROPERTIES	FINE AGGREGATE	COARSE AGGREGATE
1	Specific Gravity	2.69	2.79
2.	Water Absorbtion(%)	0.97	0.54
3.	Moisture Content	0.7(%)	0.8(%)
4.	Fineness Modulus(%)	2.456	6.687
5.	Flakiness Index(%)	-----	11.80
6.	Elongation Index(%)	-----	10.13

TABLE 6 RESULT OF MIX DESIGN

S.No.	**Design Mix**	**w/c ratio**	**Mix proportion**	**Slump (mm)**	**Compressive strength (N/mm^2)**	
					7 days	**28 days**
1	M_1	0.43	1:1.5:3	23	20.044	29.476
2	M_2	0.45	1:1.5:3	42	19.11	28.44
3	M_3	0.47	1:1.5:3	57	17.273	25.4

TABLE 7- SLUMP TEST RESULT

Concrete Mix	**Slump (mm)**	**Percentage increase w.r.t. M_0**
M_0	42	0%
M_5	45	7.14%
M_{10}	47	11.9%
M_{15}	55	30.95%
M_{20}	58	38.1%

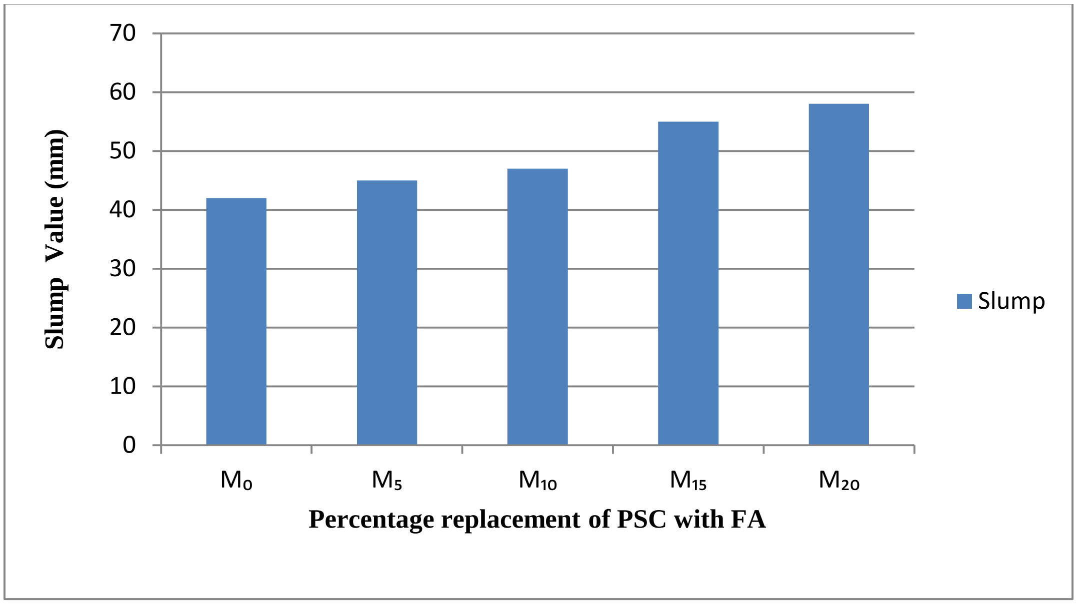

Fig-1 Graph of Consistency test

Table 8 Compressive strength test Results after 7 days

Concrete Mix	Sample	Cross-sectional area (mm^2)	Failure load (kN)	Compressive strength (N/mm^2)	Avg. compressive strength (N/mm^2)	Percentage w.r.t. M_0
M_0	1	225 $x10^2$	420	18.67	19.11	0%
	2	225 $x10^2$	430	19.11		
	3	225 $x10^2$	440	19.55		
M_5	1	225 $x10^2$	440	19.55	20.3	6.23%
	2	225 $x10^2$	460	20.444		
	3	225 $x10^2$	470	20.888		
M_{10}	1	225 $x10^2$	480	21.33	21.48	12.4%
	2	225 $x10^2$	480	21.33		
	3	225 $x10^2$	490	21.77		
M_{15}	1	225 $x10^2$	490	21.77	21.92	14.7%
	2	225 $x10^2$	490	21.77		
	3	225 $x10^2$	500	22.22		
M_{20}	1	225 $x10^2$	440	19.55	19.85	3.9%
	2	225 $x10^2$	450	20		
	3	225 $x10^2$	460	19.998		

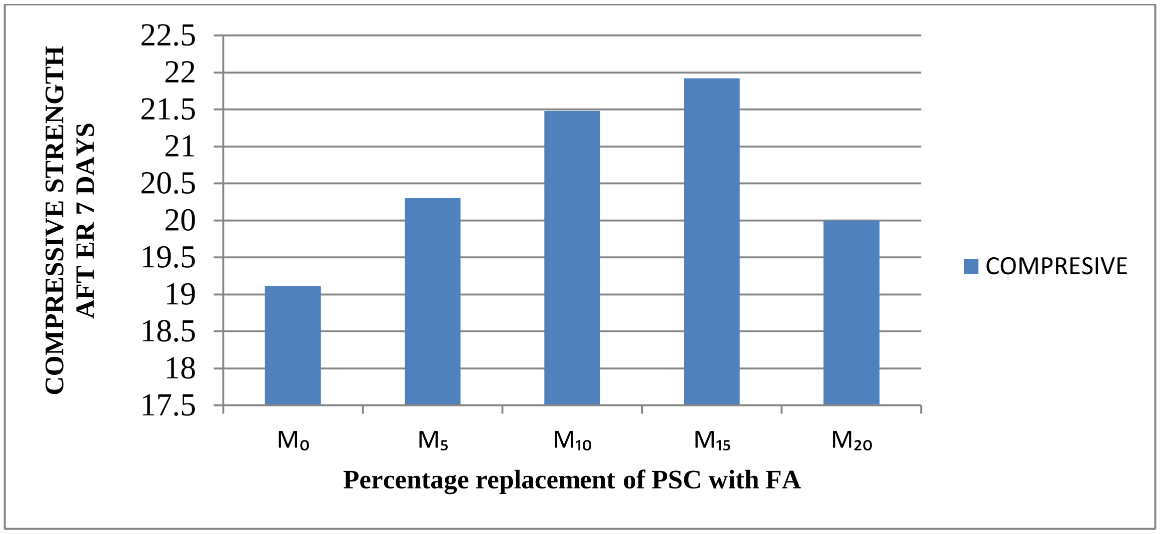

Fig2 Graph of Compressive strength of different concrete mix (cement + FA) after 7 days

Table 9 Compressive strength test Results after 28 days

Concrete Mix	Sample	Cross-sectional area (mm^2)	\Failure load (KN)	Compressive strength (N/mm^2)	Avg. compressive strength (N/mm^2)	Percentage dec. w.r.t. M_0
M_0	1	225 x10^2	630	28	28.44	0%
	2	225 x10^2	640	28.44		
	3	225 x10^2	650	28.88		
M_5	1	225 x10^2	660	29.33	30.07	5.73%
	2	225 x10^2	680	30.22		
	3	225 x10^2	690	30.66		
M_{10}	1	225 x10^2	690	30.66	31.1	9.35%
	2	225 x10^2	700	31.11		
	3	225 x10^2	710	31.55		
M_{15}	1	225 x10^2	700	31.11	31.85	11.99%
	2	225 x10^2	720	32		
	3	225 x10^2	730	32.44		
M_{20}	1	225 x10^2	640	28.44	28.9	1.62%
	2	225 x10^2	650	28.88		
	3	225 x10^2	660	29.33		

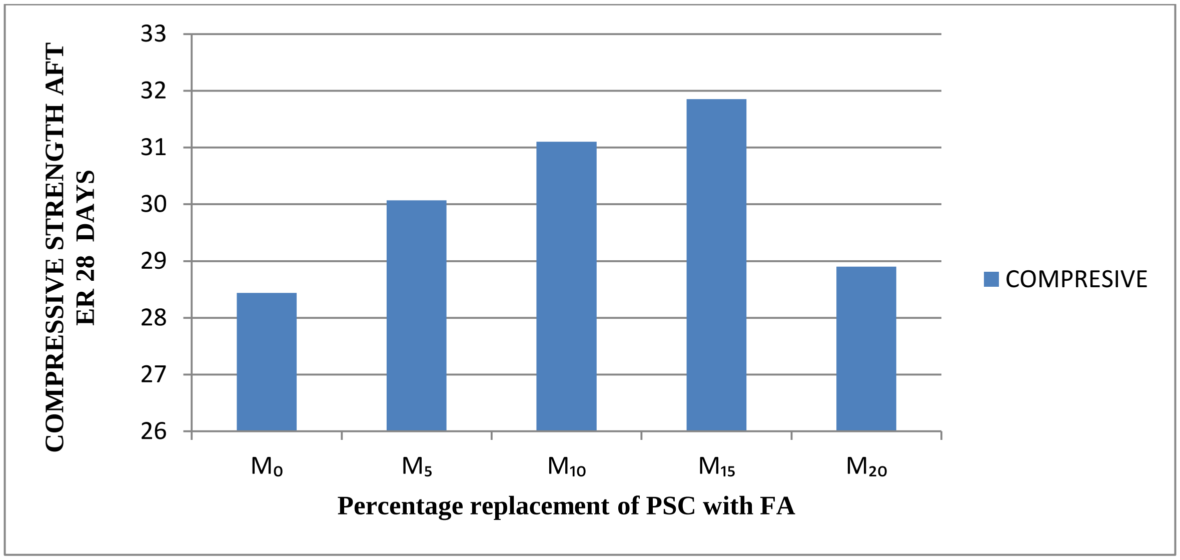

Fig.3 Graph of Compressive strength of different concrete mix (cement + FA) after 28 days

Table 10 Split tensile test data after 7 days

Mix	Sample	Failure load (KN)	Split tensile strength (N/mm^2)	Avg. split tensile strength (N/mm^2)	Percentage inc. w.r.t. M_0
M_0	1	125	1.76	1.84	0%
	2	130	1.84		
	3	135	1.91		
M_5	1	135	1.91	1.98	7.6%
	2	140	1.98		
	3	145	2.05		
M_{10}	1	145	2.05	2.07	12.5%
	2	145	2.05		
	3	150	2.12		
M_{15}	1	150	2.12	2.14	16.3%
	2	150	2.12		
	3	155	2.19		
M_{20}	1	130	1.84	1.95	5.9%
	2	135	1.91		
	3	150	2.12		

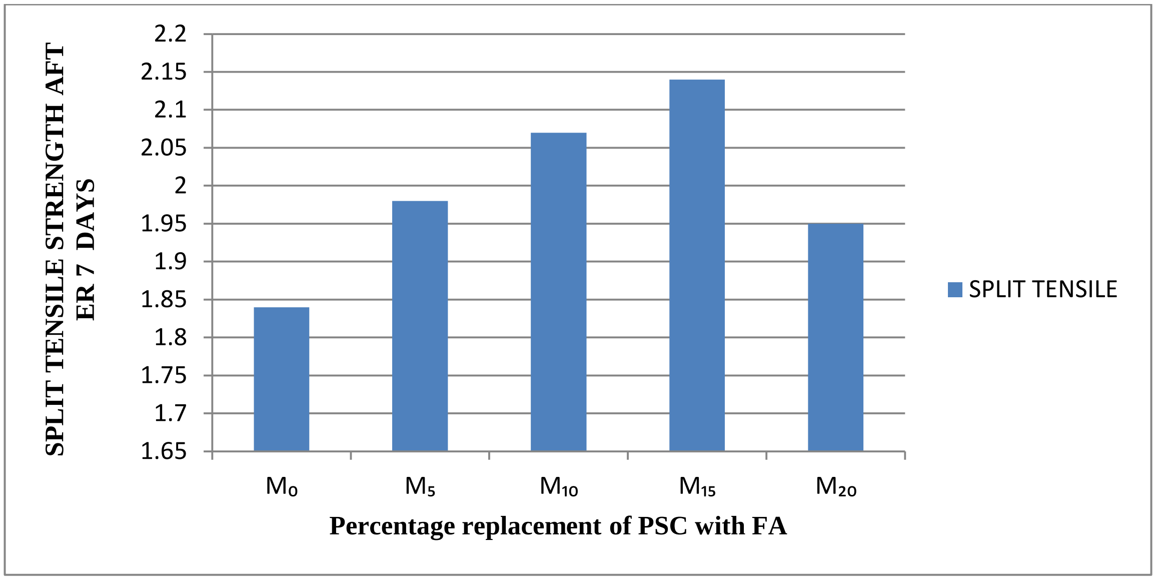

Figure 4 Graph of split tensile strength of concrete for 7 days

Table 11 Split tensile test data after 28 days

Mix	Sample	Failure load (KN)	Split tensile strength (N/mm^2)	Avg. split tensile strength (N/mm^2)	Percentage increase w.r.t. M_0
M_0	1	185	2.62	2.69	0%
	2	190	2.69		
	3	195	2.76		
M_5	1	195	2.76	2.83	5.2%
	2	200	2.83		
	3	205	2.9		
M_{10}	1	210	2.97	3.041	13.04%
	2	215	3.043		
	3	220	3.11		
M_{15}	1	215	3.043	3.07	14.12%
	2	215	3.043		
	3	220	3.11		
M_{20}	1	190	2.69	2.83	5.2%
	2	200	2.83		
	3	210	2.97		

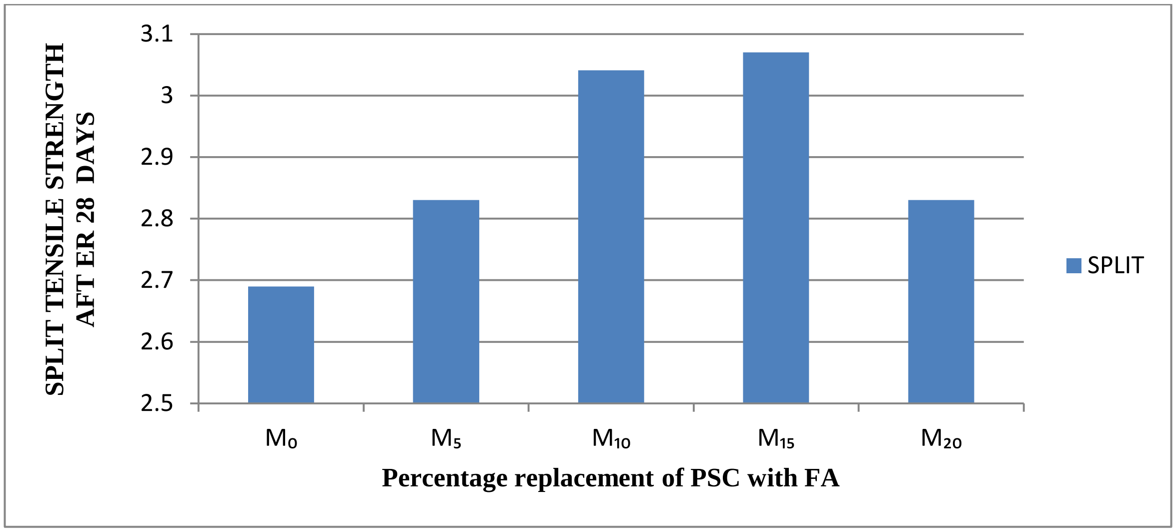

Figure 5 Graph of split tensile strength of concrete for 28 days.

Table 12 Flexural strength test data after 7 days

ConcreteMix	Sample	Span (mm)	Failure load (KN)	Flexural strength (N/mm^2) = Pl/bd^2	Avg. flexural strength (N/mm^2)	Percentage increase w.r.t. R_0
M_0	1	400	4.75	1.9	2.00	0%
	2	400	5.0	2.0		
	3	400	5.25	2.1		
M_5	1	400	5.0	2.0	2.1	5.0%
	2	400	5.25	2.1		
	3	400	5.5	2.2		
M_{10}	1	400	5.5	2.2	2.233	11.65%
	2	400	5.5	2.2		
	3	400	5.75	2.3		
M_{15}	1	400	5.25	2.1	2.3	15.0%
	2	400	5.75	2.3		
	3	400	6.25	2.5		
M_{20}	1	400	5.0	2.0	2.07	3.5%
	2	400	5.0	2.0		
	3	400	5.5	2.2		

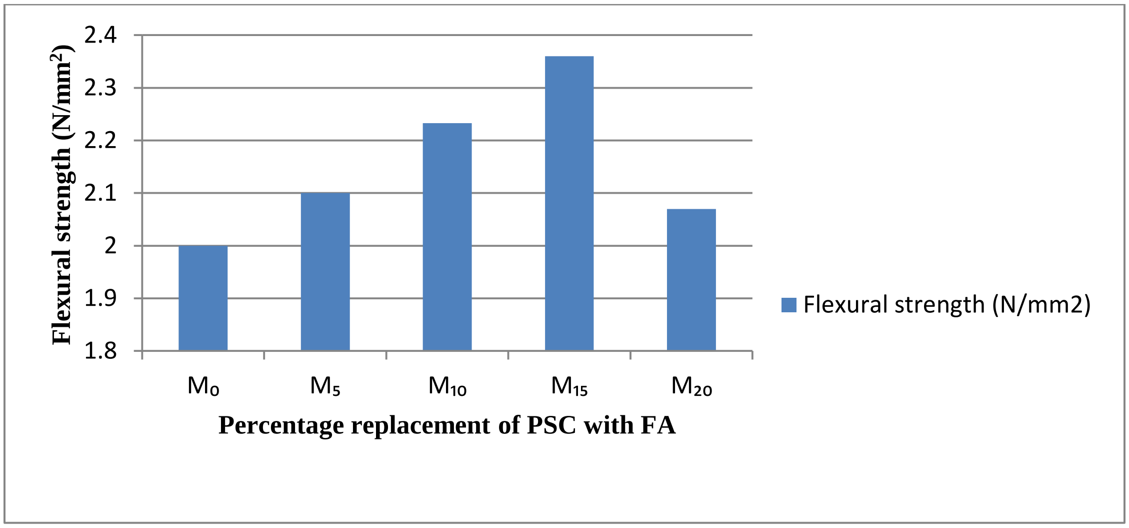

Fig 6 Flexural strength graph after 7 days

Table 13 Flexural strength test data after 28 days

Concrete Mix	Sample	Span (mm)	Failure load (KN)	Flexural strength (N/mm^2) = Pl/bd^2	Avg. flexural strength (N/mm^2)	Percentage dec. w.r.t. R_0
M_0	1	400	7.0	2.80	3.00	0%
	2	400	7.5	3.00		
	3	400	8.0	3.20		
M_5	1	400	7.5	3.00	3.10	3.33%
	2	400	7.75	3.10		
	3	400	8.0	3.20		
M_{10}	1	400	7.75	3.10	3.20	6.67%
	2	400	8.0	3.20		
	3	400	8.25	3.30		
M_{15}	1	400	8.0	3.20	3.33	11.11%
	2	400	8.25	3.30		
	3	400	8.75	3.50		
M_{20}	1	400	6.75	2.7	3.067	2.23%
	2	400	7.75	3.1		
	3	400	8.5	3.4		

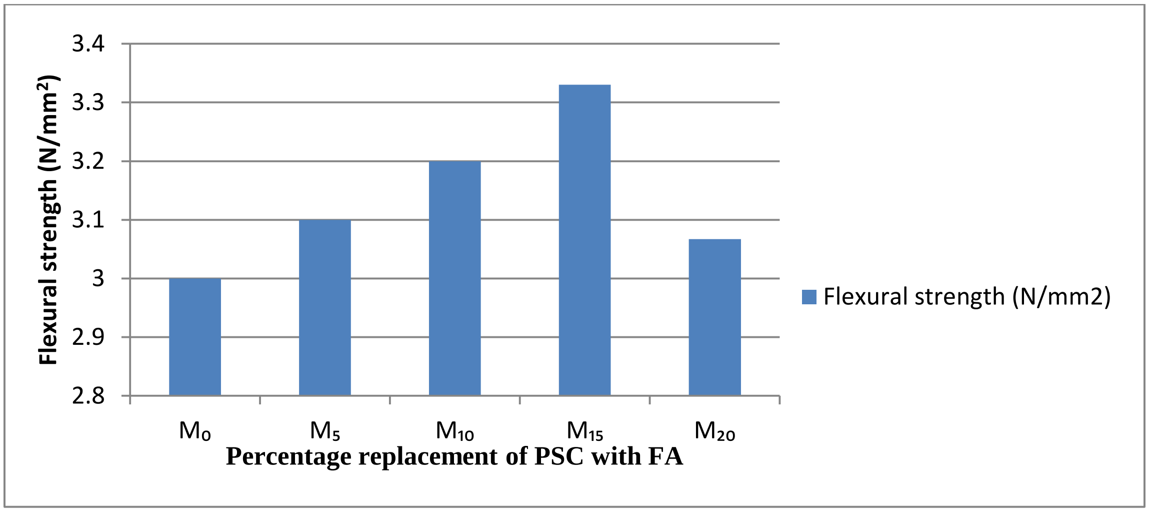

Fig 7 Flexural strength graph after 28 days